5 Why Breastfeeding?

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Expected Key Learning Outcomes

- The importance of optimum nutrition in the first months after birth
- The effect of early nutrition on later life
- The importance of good health and nutrition for mothers during pregnancy and throughout lactation

5.1 Introduction

There is no other period of time in human life when the quantity and quality of nutritional supply are of greater importance than during the first months after birth. This is due to the extremely rapid growth of infants who normally double their birth weight in 4–5 months and triple it in the first year; such a growth rate demands a very high requirement of energy and nutrients per kilogram of body weight [1], [2]. The capacity to compensate for a diet that is insufficient in quantity or inadequate in nutritional value is limited. Body reserves of nutrients are very restricted and, particularly during the first months of life, some body functions are not fully developed, such as nutrient absorption, metabolism, and renal conservation. In addition to this fast rate of body mass gain there is a rapid development and differentiation of tissues and organs. During this period of developmental plasticity, environmental cues such as nutrition and metabolism have modifying effects on growth, development, and long-term function and health. An increasing body of evidence indicates that nutrition, particularly during the first two years of life, has a marked impact on later physiology, health, and disease risks; this is commonly referred to as the ‘metabolic programming of life-long health and disease’ or the ‘developmental origins of adult health’ [1], [3], [4].

5.2 The Evolution of Lactation

Breastfeeding is the natural form of infant feeding and is universally recommended [5]. The composition of human milk is believed to have developed during a very long evolutionary process to match the needs of both lactating women and their infants optimally. Lactation and milk feeding in mammalian species is believed to have evolved over a period of about 250–300 million years, and to have originated from synapsid animals that provided fluid from cutaneous glands to protect their parchment-shelled eggs from desiccation [6], [7]. These ancestral cutaneous glands are thought to have evolved by combining features of skin glands into new functional entities. Gland secretions were then provided with antimicrobial properties to protect eggs and hatchlings from infection, and organic components to supplement offspring nutrition [8]. The immune properties of milk from various mammalian species show wide variation in anti-inflammatory and immunomodulating agents, including immunoglobulins, iron-binding proteins, lysozyme, oligosaccharides, and leukocytes. This variability appears to compensate for differences in developmental delays in early postnatal production of antimicrobial factors among species [9], [10]. Moreover, the composition and concentrations of different immunological agents in mammalian milks relate to differences in placental type and function, lactation pattern, and environments and also follow different evolutionary strategies.

Similarly, the evolutionary development of highly nutritious milks has led to diverse variation in mammary gland anatomy, milk output, length of lactation, and nutrient content (Table 5.1, Table 5.2), and in the relative contribution of milk feeding to the offspring’s total nutrient supply during their initial growth period. For example, the wide inter-species variation in milk protein content, a key driver of offspring growth, is...
closely related to offspring growth velocity (Fig. 5.1). The relatively low protein concentration in human milk is an adaptation to the lower needs of human infants who have slower weight gain rates compared to, for example, calves or kittens. Moreover, the protein supply in human milk falls substantially with increasing duration of lactation. The protein intake per kilogram body weight of a breastfed infant at 6 months represents only about 55% of the intake after birth (Fig. 5.2). Underlining evolutionary adaptation of lactation to the needs of the species, this change is in accordance with the decrease in protein requirement with increasing postnatal age, which is a consequence of a slowing of infant growth rate.

Recent genome studies provide support for the hypothesis that during the evolution of lactation, the maternal energy cost of breastfeeding has been limited while aiming to maximise offspring survival. In effect, this would have promoted survival of the maternal-offspring pair and therefore survival of the species. The genome analysis of

<table>
<thead>
<tr>
<th>Cellular components</th>
<th>Humoral and other components</th>
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<tbody>
<tr>
<td>Neutrophil, granulocyte, macrophages</td>
<td>Immunoglobulins (sIgA, IgG, IgM, IgD)</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>Complement and complement receptors</td>
</tr>
<tr>
<td>Mammary gland epithelial cell membranes</td>
<td>Toll-like receptors</td>
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<tr>
<td>Milk fat globoli membranes</td>
<td>Soluble CD14</td>
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<td></td>
<td>β-Defensin-1</td>
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<tr>
<td></td>
<td>Cytokines, e.g. IL-10, TGFβ</td>
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<tr>
<td></td>
<td>TNFα and IL-6 receptors</td>
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<tr>
<td></td>
<td>IL-1 receptor antagonist</td>
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<td></td>
<td>κ-Casein, α-lactalbumin</td>
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<td></td>
<td>Lysozyme</td>
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<td></td>
<td>Lactoferrin, lactoferricin B and H</td>
</tr>
</tbody>
</table>

Modified from [57].

| Tab. 5.2 Milk composition (% weight) among nine species. |
|----------------|----------------|-------------|-------------|-------------|-------------|
|                 | Water  | Protein | Fat  | Lactose | Ash  |
| Human            | 87.7   | 1.8     | 3.6  | 6.8      | 0.1       |
| Cow              | 86.6   | 3.4     | 4.6  | 4.9      | 0.7       |
| Buffalo          | 84.2   | 3.9     | 6.6  | 5.2      | 0.8       |
| Sheep            | 79.4   | 3.5     | 8.6  | 4.3      | 1.0       |
| Pig              | 89.6   | 1.3     | 4.8  | 3.4      | 0.9       |
| Dog              | 75.4   | 11.2    | 9.6  | 3.1      | 0.7       |
| Rat              | 68.3   | 11.3    | 14.8 | 2.9      | 1.5       |
| Whale            | 70.1   | 9.5     | 19.6 | 1.8      | 1.0       |
| Seal             | 32.3   | 11.2    | 34.8 | 2.6      | 0.9       |
seven mammalian species (human, cow, dog, mouse, rat, opossum, and platypus) indicates a high degree of conservation of milk genes and mammary genes. Such conservation seems to have evolved more slowly than for other genes, even in cows selectively bred for effective milk production [7]. The most variable parts of the lactome were those with nutritional or immunological characteristics. This leads to speculation that evolutionary selection (specifically of these genes) occurred in response to different environmental and nutritional needs and to infectious challenges. Interestingly, most conserved genes are those for proteins of the milk fat globule membrane, suggesting they may have a central biological role.

In spite of its high metabolic cost, the evolution of lactation has been accompanied by the global biological success of mammalian species. This supports the hypothesis that there are major benefits to lactation due to the nutritional and antimicrobial properties of milk and the associated extended period of mother-infant contact. The regular and frequent transfer of milk, particularly in humans and other non-human primates, provides offspring with close interaction with their mother and therefore more learning opportunities, which may have facilitated the development of high levels of intelligence found in humans and other primates.

While we have yet to learn much about the evolutionary process of lactation over the last 250–300 million years and the biological consequences for humans today, the available evidence indicates that human breastfeeding has evolved to be highly adapted to the needs of both mothers and infants. A tempting question is whether new areas of vulnerability might arise from the discordance be-

Fig. 5.1 Protein content of mammalian milks relative to time to doubling of offspring weight. Note the low human protein milk content in humans matching relatively slow offspring growth.

Fig. 5.2 Decrease in milk protein intake in a breastfed human infant in the first six months reflecting the decrease in infant growth rate. Milk protein intake is calculated as 75% of crude protein intake.
tween the slow evolutionary adaption of the human genome affecting biological characteristics such as breastfeeding and human milk composition and the rapid environmental and human lifestyle changes particularly within the last century. These questions warrant investigation in future studies.

5.3 Assessing Health Effects of Breastfeeding

There is considerable data supporting the health effects and benefits of breastfeeding for mother and infant, and these have been evaluated in systematic reviews [10], [11], [12], [13], [14], [15]. Given that breastfeeding is widely considered as the natural and optimal mode of infant feeding, it is generally thought unethical to randomise infants to either breastfeeding or breast milk substitutes. As such, the evidence is almost entirely based on epidemiological data from observational studies. A limitation to this is that the decision to breastfeed and the duration and exclusivity of breastfeeding are associated with a variety of factors that predict health outcomes, e.g., socioeconomic status, education, and lifestyle factors including smoking habits, physical activity, dietary choices, and use of preventive healthcare. Thus, there is a high risk that the effects and effect sizes of breastfeeding are overestimated if there is no adjustment for such confounding factors. Even with adequate adjustment, there remains the risk of residual confounding, partly because not all confounders can be quantitatively assessed. A review and analysis by Ip and co-workers details the methodological issues and considerable differences in the quality of studies assessing breastfeeding effects. This report rated study quality with regard to study methodology when evaluating the evidence, a practice not often considered by other authors. Ip, et al. concluded that prospective longitudinal cohort studies provide a better opportunity for adequate assessment of confounding variables than retrospective or cross-sectional studies [14].

The author of this article is aware of only one randomised controlled trial performed at the end of the 20th century. In this trial conducted in four antenatal clinics in Nairobi, Kenya, women infected with human immunodeficiency virus type 1 (HIV-1) infection were randomly assigned to either breastfeeding (n=185) or formula feeding (n=186) their infants to assess potential effects on vertical HIV transmission [16], [17]. Mortality rates adjusted for HIV-1 infection status, morbidity, and nutritional status were monitored during the first two years of life. Today, enhanced knowledge of strategies to mitigate the risk of HIV transmission during breastfeeding and particularly effective antiretroviral therapy has changed the approaches to breastfeeding in HIV-positive women in low income countries. Therefore, such a randomised trial in HIV-positive women would no longer be feasible today.

However, it has been considered ethical to cluster-randomise hospitals to standard or enhanced breastfeeding promotion. With the aim to evaluate the effects of breastfeeding promotion in hospitals on breastfeeding success, such a cluster-randomised trial (the PROBIT trial) was performed in 31 hospitals in Belarus [18]. The PROBIT trial compared an experimental intervention modelled on the World Health Organization and United Nations Children’s Fund Baby-Friendly Hospital Initiative with a control intervention. The experimental intervention emphasised health care worker assistance with initiating and maintaining breastfeeding, and lactation and postnatal breastfeeding support [18]. Although not primarily designed for such a purpose, the study followed children to later ages to evaluate the health effects of varying breastfeeding duration [19], [20]. Studies have also randomised breastfed infants to earlier or later introduction of complementary feeding, and hence to different durations of exclusive or predominant breastfeeding [21], [22], and to earlier or later introduction of specific complementary feeds [23], [24], [25]. These rare randomised trials are extremely valuable, but their conclusions are limited to the questions originally addressed. The discussion on the health effects of breastfeeding presented here is based primarily on observational studies, with the caveat that the reported effects and effect sizes are likely to be confounded by oth-
er variables usually associated with breastfeeding (e.g., socio-economic status and health promoting behaviour within families) that are generally difficult to fully adjust for.

5.4 Breastfeeding and Maternal Health

Breastfeeding requires energy that is derived both from the maternal diet and from lipolysis of maternal fat depots [26]. Breastfeeding, particularly breastfeeding of longer duration, such as for more than three months, therefore has the potential to facilitate regression of maternal fat deposits that accumulate during pregnancy [27]. However, a recent meta-analysis concluded that the role of breastfeeding on postpartum weight change remains unclear [13].

While depression during pregnancy predicts shorter duration of breastfeeding, it remains unclear as to whether breastfeeding has any effect on the severity of maternal postpartum depression [13]. R. Chowdhury, et al. identified 12 studies that explored associations of breastfeeding and lactational amenorrhoea [13]. They concluded that amenorrhoea at six months after birth was 23% more likely to occur with exclusive or predominant breastfeeding versus no breastfeeding and 21% more likely versus partial breastfeeding. Thus, exclusive or predominant breastfeeding can contribute to spacing of childbirth on a population basis but should not be considered a secure contraceptive approach.

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With respect to long-term effects of breastfeeding on maternal health, a very large number of studies have explored its association with the occurrence of mammary carcinoma. In a meta-analysis of 98 studies, ever breastfeeding was associated with a 22% risk reduction of developing breast cancer later. The risk reduction was 7% for breastfeeding for less than six months, 9% for 6–12 months, and 26% for breastfeeding for more than 12 months [13]. It has been estimated that one case of breast cancer could be prevented among every 200 women who breastfeed for more than 12 months, assuming a lifetime prevalence of 12.9% [28], [29]. However, there is evidence of publication bias, and therefore effect sizes of the association between breastfeeding and breast cancer prevention may be overestimated [13].

Additionally, in a meta-analysis of 30 studies, a 30% reduction on the risk of later ovarian carcinoma was reported in women who breastfed at any time compared to those who never breastfed [13], with some indication of a greater effect with longer versus shorter breastfeeding duration. The estimated effect size was slightly lower when the analysis was restricted to high quality studies only.

Studies on bone mineral density report heterogeneous results, with no conclusive evidence of the effect of breastfeeding on women’s risk of osteoporosis later in life [13].

5.5 Breastfeeding and Infant Health

Breastfeeding with its major nutritional and immunological benefits was the only safe choice for infant feeding in European countries until the late 19th century. Based on the empirical evidence of the major benefits of breastfeeding for child health, the Law Book of the State of Prussia (1792) introduced a legal obligation that mothers must breastfeed to protect their children. This Prussian law book included the following statements:

§67. A healthy mother is obliged to breastfeed her child.
§68. How long she should breastfeed shall be decided by the father.
§69. But if the health of mother or child would suffer from his decision, he must subdue under the opinion of the expert.

Until the late 19th century, breastfeeding by wet nurses was the only reasonable alternative to breastfeeding by the infant’s own mother. As early as in the 10th century AD, the Persian Canon of Medicine by Avicenna emphasised the role of wet nursing, stating, ‘Breast milk is the best for the child …’ and ‘Is the mother prevented from breast-feeding, the wet nurse should be between 25 and 35 years of age, healthy, of good and hon-
ourable manners, and having given birth 1½ to 2 months before.’ Wet nurses remained popular in the 18th and 19th centuries among affluent city families in Europe. In 1780, more than 80% of infants born in the city of Paris were reported to be fed by wet nurses, and 4,000–5,000 wet nurses were employed in the city of Hamburg in the 18th century [30].

In 1865, the German chemist Justus von Liebig developed the first suitable breast milk substitute based on chemical analysis of human milk composition [31]. This triggered the development of bottle milks that could serve as feasible replacements for breastfeeding. In 1885, in Germany, the mortality of breastfed babies up to the age of 10 months was 6- to 8-fold lower for breastfed infants than for infants fed the available animal milk preparations (Table 5.3). Today, the mortality of non-breastfed infants in low and low-to-medium income countries remains considerably higher than that of breastfed babies [32]. A recent systematic review of studies in low and low-to-medium income countries reported an increased risk of all-cause mortality in predominantly (relative risk 1.5), partially (relative risk 4.8), and non-breastfed (relative risk 14.4) infants compared to exclusively breastfed infants [33]. However, the quality of the evidence was poor to very poor [33].

The reported effects of breastfeeding on infant mortality in Europe in the 19th century, and in low- and low-to-medium income countries today, appears to be primarily related to the reduced risk of infection by breastfeeding. A meta-analysis of five cohort studies of good and moderate methodological quality showed that breastfeeding was associated with a significant reduction in the risk of acute otitis media. Comparing breastfeeding at any time with exclusive formula feeding, the risk of acute otitis media was reduced by 23% (95% CI: 9% to 36%) [14]. When comparing exclusive breastfeeding with exclusive formula feeding, the reduction was 50% (95% CI: 30% to 64%) after either more than three or six months duration [14]. These results were adjusted for potential confounders. Similarly, a review of 24 studies from the USA and Europe indicated that all forms of breastfeeding were associated with a risk reduction for acute otitis media; odds ratios were 0.57 with exclusive breastfeeding for six months and 0.67 for breast feeding at any time versus never breastfeeding [34]. Among 100 infants breastfed for 6 months, an estimated 13 cases of acute otitis media (incidence 27%) could be prevented compared to formula feeding [35], [29]. Breastfeeding has also been associated with a one half to one third reduction in the risk of acute gastroenteritis.

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>Mother married</th>
<th>Fed animal milk</th>
<th>Mother unmarried</th>
<th>Fed animal milk</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>196</td>
<td>1,028</td>
<td>267</td>
<td>1,252</td>
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<tr>
<td>1</td>
<td>76</td>
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<tr>
<td>9</td>
<td>47</td>
<td>259</td>
<td>45</td>
<td>260</td>
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<tr>
<td>10</td>
<td>59</td>
<td>218</td>
<td>81</td>
<td>276</td>
</tr>
<tr>
<td>Total mortality (%)</td>
<td>7.3</td>
<td>46.4</td>
<td>8.5</td>
<td>68.1</td>
</tr>
</tbody>
</table>

Data from Prof. Arthur Schlossmann, from the Children’s Hospital, Heinrich Heine Universität Düsseldorf collection, Germany
Accordingly, breastfeeding 100 infants for six months could prevent 15–63 diarrhoea episodes (at an annual incidence of 0.9–1.9 episodes) and 2–6 hospital admissions [29].

Additionally, breastfeeding has been linked with a 15–36% reduction in mortality from ‘sudden infant death syndrome’ (SIDS) [14], [36]. It is therefore estimated that one SIDS death could be prevented per 10,000 infants breastfed [29], [37].

Systematic reviews and meta-analyses of observational studies report that breastfeeding may reduce the risk for disorders later in life [5], [38], [14], [39] such as obesity (risk reduced by 12%; about three cases of obesity prevented per 100 breastfed infants) [38], [29], [40]. Added plausibility for a causal protective effect of breastfeeding against later obesity arises from a randomised controlled trial. This trial demonstrated that a reduction in protein intake in infancy to levels closer to those provided by breastfeeding afforded good protection against obesity at school age [41], [42]. With regard to the underlying mechanism, we consider growth patterns in infancy a major predictor of later obesity risk [4], [43]. Children who gain weight more rapidly during the first and/or second year of life have a marked increase in risk of becoming overweight and obese later in life [4], [43]. In the Darling Study in California, body weights of breastfed and bottle-fed infants were found to be similar during the first months of life, although previously bottle-fed infants were significantly heavier than previously breastfed infants from 6–24 months [44], [45], [46] (Fig. 5.3). Interestingly, infant growth was similar between infants breastfed exclusively for four and six months [21] and the protective effects against obesity appeared to be similar for exclusively and predominantly breastfed infants but were greater with longer duration of breastfeeding [47], [48] (Fig. 5.4).

Breastfeeding has also been associated with a modest risk reduction of asthma (by about 10%) and atopic dermatitis (by about 5%). However, a major issue influencing study quality was the frequent failure to adjust for key confounders, most commonly socio-economic status and family history of allergy, and the definitions of outcome measures were very variable between studies [49], [50]. In the cluster randomised PROBIT trial, breastfeeding promotion intervention resulted in an increase in exclusive breast feeding at three months (44.3% versus 6.4%; p < 0.001) and a significantly higher prevalence of any breastfeeding at all ages up to and including 12 months. However, no reduction in the risks of allergic symptoms and diagnoses or positive skin prick tests were found among the 13,889 children who were followed up at the age of 6.5 years [20]. In fact, after exclusion of six sites (three experimental and three control) with suspiciously high rates of positive skin prick tests, sensitisation risk was significantly increased in the experimental group for four of the five antigens versus the control [20].

A randomised trial tested whether early introduction of allergenic foods (i.e., peanut, cooked egg, cow’s milk, sesame, white fish, and wheat) in the diet of breastfed infants would protect against the development of food allergy [22]. Some 1,303

![Fig. 5.3](image_url) Growth (standard deviation scores of weight for length) of breast and bottle fed infants up to the age of 24 months.
exclusively breast-fed infants aged three months were randomly assigned to the introduction of six allergenic foods at the age of three months or to exclusive breastfeeding to six months of age with the introduction of the allergenic foods thereafter. In the intention-to-treat analysis, there was a non-significant trend to slightly less food allergy with early compared to later introduction of allergenic foods (5.6% versus 7.1%). In the per-protocol analysis, the prevalence of any food allergy was significantly lower in the early-introduction group than in the standard-introduction group (2.4% versus 7.3%, \( p=0.01 \)), as was the prevalence of peanut allergy (0% versus 2.5%, \( p=0.003 \)) and egg allergy (1.4% versus 5.5%, \( p=0.009 \)) [22]. In this study, the prevalence of allergy to peanut and egg as well as the prevalence of positive responses on skin prick testing to peanut, egg, and raw egg white were inversely associated with the consumed amount of solid foods containing antigens. These data raise the question as to whether exclusive breastfeeding for six months, which is an important and life-saving strategy for promoting health and preventing infections in low-income countries, may be less optimal for infants in affluent countries where there is a relatively low threat of common infections but a high disease burden due to allergy. It appears possible that introduction of smaller quantities of allergenic foods may have protective effects.

Breastfeeding has also been associated with strengthening maternal infant bonding and promoting offspring cognitive development. After adjustment for major confounders, previously breastfed adolescents and adults have mean IQ test results that are 2–3 points higher compared to previously non-breastfed subjects [38], [15]. One causal factor appears to be the lipids in human milk. These comprise the long-chain polyunsaturated fatty acids, omega-3 docosahexaenoic acid (DHA) and omega-6 arachidonic acid (ARA), which are incorporated in considerable amounts into the lipid-rich brain of growing infants [51], [52]. Indeed, magnetic resonance imaging of the brain structure of 133 healthy infants and young children revealed that breastfeeding led to increased white matter development in later maturing frontal and association brain regions. Positive relationships between white matter microstructure and breastfeeding duration are also exhibited in several brain regions; these are anatomically consistent with observed improvements in cognitive and behavioural performance measures [53]. Given that previous morphometric brain imaging

Fig. 5.4 Lower risk of overweight and obesity at early school age among more than 9,000 children in Bavaria, Germany (adjusted for confounding variables) in children ever breastfed versus never breastfed.
studies showed that increased white matter volume, sub-cortical grey matter volume, and parietal lobe cortical thickness were linked to higher IQ values, these findings support the hypothesis that constituents of human milk may beneficially affect both brain structure and function. Gene environment interaction studies strengthen the conclusion of a causal effect of breastfeeding on cognitive development. In the UK ALSPAC study, 5,934 children were tested for IQ at the age of about eight years; those who showed homozygosity for less common variants of the Fatty Acid Desaturase (FADS) gene had the largest IQ benefit from breastfeeding. Homozygosity confers a low ability to synthesise DHA and ARA endogenously, and breastfeeding (which provides DHA and ARA) therefore appears to have compensated for the more limited endogenous conversion in these children [54], [51], [55]. The apparent small effect size on IQ values may be of considerable practical relevance for achievements in life. In a prospective cohort study in over 3,000 people followed from birth to the age of 30 years, those who were breastfed for one year had an IQ benefit of 3.8 points, a 0.9 years longer time in education, and a 23% higher income compared to those not breastfed (all adjusted for other confounding factors) [56].

5.6 Conclusion

Breastfeeding is the natural choice of infant feeding. As a consequence of a long-lasting evolutionary process, it is well adapted to the biology of both mothers and infants. There are numerous accounts of the major benefits of breastfeeding for both maternal and infant health. However, uncertainties remain on actual effect sizes due to the observational nature of most of the evidence, which is prone to (residual) confounding. Women who breastfeed may particularly benefit from enhanced regression of maternal fat deposits that accumulate during pregnancy, and from a reduction in the risk of mammary and ovarian carcinomas. In breastfed infants, the risk of infections, particularly of acute otitis media and acute gastroenteritis, can be attenuated, with an apparent major benefit for survival in low and low-to-medium income countries. Breastfeeding is also associated with a reduced risk of sudden infant death syndrome and with a consistent, modest risk reduction of later obesity by about 12%. A small risk reduction for asthma and eczema has been reported, but some methodological issues and uncertainties exist. There is good evidence for a small benefit of breastfeeding on later cognitive ability, which has been associated with a major advantage for later educational achievement and income. These data should prompt health care professionals around the world, along with policy makers and the general public, to firstly, actively promote, protect, and support breastfeeding, and secondly, support women’s good health and high quality of nutrition before and during pregnancy, and during lactation as these directly and positively impact on milk and breastfeeding outcomes.

8 Key Points

- There is intensive and rapid infant growth alongside tissue/organ development and differentiation during the first few months of life, therefore optimum nutrition in the form of breastfeeding is required to meet the needs of the growing infant
- Nutrition early in life has a marked impact on later physiology, health, and disease risks; it metabolically ‘programmes’ the future health of the infant
- Breastfeeding is the best choice for infant feeding and ensuring maternal good health. High quality of nutrition before and during pregnancy and lactation can directly and positively impact milk composition and breastfeeding outcomes
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5.6 Conclusion


